

Exhibit J

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5 **Digital Imaging and Communications in Medicine (DICOM)**

6
7 *Supplement 61: JPEG 2000 Transfer Syntaxes*

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18 **DICOM Standards Committee, Working Group 4 Compression**

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Foreword

59

60 This Supplement has been prepared by the DICOM Working Group 4 (Compression) according to
61 the procedures of the DICOM Committee.

62 The DICOM Standard is structured as a multi-part document using the guidelines established in the
63 following document:

64 - ISO/IEC Directives, 1989 Part 3: Drafting and Presentation of International Standards.

65 This document is a Supplement to the DICOM Standard. It is an extension to PS 3.3, 3.4 and 3.6 of
66 the published DICOM Standard, which consists of the following parts:

- | | | |
|----|---------|---|
| 67 | PS 3.1 | - Introduction and Overview |
| 68 | PS 3.2 | - Conformance |
| 69 | PS 3.3 | - Information Object Definitions |
| 70 | PS 3.4 | - Service Class Specifications |
| 71 | PS 3.5 | - Data Structures and Encoding |
| 72 | PS 3.6 | - Data Dictionary |
| 73 | PS 3.7 | - Message Exchange |
| 74 | PS 3.8 | - Network Communication Support for Message Exchange |
| 75 | PS 3.9 | - Point-to-Point Communication Support for Message Exchange |
| 76 | PS 3.10 | - Media Storage and File Format for Data Interchange |
| 77 | PS 3.11 | - Media Storage Application Profiles |
| 78 | PS 3.12 | - Media Formats and Physical Media for Data Interchange |
| 79 | PS 3.13 | - Print Management Point-to-Point Communication Support |
| 80 | PS 3.14 | - Grayscale Standard Display Function |
| 81 | PS 3.15 | - Security Profiles |
| 82 | PS 3.16 | - Content Mapping Resource |

83 These parts are related but independent documents.

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Scope and Field of Application85 **INTRODUCTION.**

86 Additional DICOM Transfer Syntaxes are introduced to add support for the JPEG 2000 Part 1 ~~lossy~~
 87 lossless and lossy compression schemes.

88 When first introduced, DICOM contained support for the lossless and lossy compression processes
 89 defined in the “original” JPEG standard, ISO 10918-1. Though that standard supported various
 90 different processes, in practice only those based on sequential block-based DCT Huffman entropy
 91 coding for lossy compression and predictive coding with Huffman entropy coding for lossless
 92 compression have been widely used.

93 Given that there are both real and perceived limitations with 10918-1 JPEG, WG 4 began to
 94 investigate alternatives, particularly those based on wavelet transformation, multi-resolution analysis
 95 and more sophisticated entropy coders than Huffman coding.

96 Working Group 4 set aside its effort to develop its own (medically specific) image date compression
 97 standard when the call for proposals for “JPEG 2000” was announced by ISO/IEC JTC1/SC29/WG1.
 98 Since then, efforts have been directed towards developing JPEG 2000 (ISO 15444-1), and ensuring
 99 that it provides features which are needed for medical imaging.

100 The use of ISO/IEC 15444-1 does not necessarily result in improved compression performance for
 101 any particular application (in terms of quantitative or qualitative measures of image fidelity,
 102 preservation of diagnostically significant information, consumption of resources such as memory or
 103 compression and decompression speed). However, JPEG 2000 offers additional features that may
 104 be important for some medical applications in which DICOM is used. These features include
 105 progressive and embedded spatial and contrast resolution, progression to lossless reconstruction,
 106 regions of interest and so on.

107 At the present time, only the features included in Part 1 of JPEG 2000 (ISO/IEC 15444-1) are
 108 included in this proposal. All JPEG 2000 implementations are required to support all features of Part
 109 1 and accordingly this is expected to be a “baseline” for all available codecs. Other proposed parts of
 110 JPEG 2000 included additional features that may be of interest for medical imaging, such as
 111 alternative quantization methods (such as TCQ) and wavelet transforms in more than two
 112 dimensions (potentially useful for hyper-spectral and 3D volume data compression). If these
 113 “extensions” to JPEG 2000 prove viable and receive widespread support by codec implementers
 114 then they could be added as additional separate Transfer Syntaxes in DICOM.

115 The introduction of the JPEG 2000 transfer syntaxes is in no way intended to imply that the
 116 compression schemes already incorporated in the standard, some of which are widely used, are in
 117 some way “inferior”. Likewise, the introduction of JPEG 2000 does not imply endorsement of the
 118 scheme for any particular clinical or diagnostic application. The standard simply makes the scheme
 119 available; it is the responsibility of individual users, vendors, regulatory agencies and professional
 120 societies to ascertain the safety and efficacy of the use of any tool for a particular clinical application.

121 At the same time as introducing new Transfer Syntaxes, the opportunity is taken to retire those
 122 existing Transfer Syntaxes that are not in use. Also, the unused and deprecated ARGB Photometric
Interpretation is also retired.

124 **DESIGN DECISIONS**

125 The approach proposed is to encapsulate JPEG 2000 bit streams in exactly the same manner as is
 126 currently used for JPEG (10918-1), JPEG-LS and RLE. This implies that:

- 127 • Undefined length pixel data contains one or more sequence-item-like fragments preceded by
 128 a possibly empty offset table.

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- 129 • Each frame (or an entire single frame image) will be in one or more fragments.
- 130 • The optional JP2 file format header defined in 15444-1 is not included, only the actual
131 compressed JPEG bit stream (this is the same as for JPEG which does not include a JFIF
132 header in the DICOM encapsulation and JPEG-LS which does not include a SPIFF header).
- 133 • Information that is not specified in the JPEG 2000 bit stream, such as what color component
134 corresponds to each compressed component, is specified in the DICOM attributes, such as
135 Photometric Interpretation (again, just like JPEG, JPEG-LS and RLE).
- 136 • Separate transfer syntaxes are defined for reversible and irreversible processes, in order to
137 be able to negotiate reversible transfers.

138 FORM OF THIS SUPPLEMENT

139 This supplement adds new Transfer Syntaxes to support JPEG 2000, adds new Photometric
140 Interpretations compatible with those used in JPEG 2000 encoded bit streams, and retires unused
141 JPEG Transfer Syntaxes.

142 Since this document proposes changes to existing Parts of DICOM, the reader should have a
143 working understanding of the Standard. This proposed Supplement includes a number of Addenda
144 to existing Parts of DICOM:

- 145 - PS 3.3 Addendum: Information Object Definitions
- 146 - PS 3.5 Addendum: Data Structures and Encoding
- 147 - PS 3.6 Addendum: Data Dictionary
- 148 - PS 3.11 Addendum: Media Application Profiles

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158 **Changes to**

159 **NEMA Standards Publication PS 3.3-2000**

160

161 *Digital Imaging and Communications in Medicine (DICOM)*

162 *Part 3: Information Object Definitions*

163 *Add JPEG 2000 Photometric Interpretations to Image Pixel Module C.7.6.3:*

164 **C.7.6.3Image Pixel Module**

165 Table C.7-9 specified the Attributes that describe the pixel data of the image.

166 ...

167 **C.7.6.3.1 Image Pixel Attribute Descriptions**

168 **C.7.6.3.1.1 Samples Per Pixel**

169 Samples per Pixel (0028,0002) is the number of separate planes in this image. One, three, and four
170 image planes are defined. Other numbers of image planes are allowed, but their meaning is not
171 defined by this Standard.

172 For monochrome (gray scale) and palette color images, the number of planes is 1. For RGB and
173 other three vector color models, the value of this attribute is 3. For ARGB and other four vector color
174 models, the value of this attribute is 4.

175 All image planes shall have the same number of Rows (0028,0010), Columns (0028,0011), Bits
176 Allocated (0028,0100), Bits Stored (0028,0101), High Bit (0028,0102), Pixel Representation
177 (0028,0103), and Pixel Aspect Ratio (0028,0034).

178 The data in each pixel may be represented as a "Composite Pixel Code". If Samples Per Pixel is
179 one, the Composite Pixel Code is just the "n" bit pixel sample, where "n" = Bits Allocated. If Samples
180 Per Pixel is greater than one, Composite Pixel Code is a "k" bit concatenation of samples, where "k" =
181 Bits Allocated multiplied by Samples Per Pixel, and with the sample representing the vector color
182 designated first in the Photometric Interpretation name comprising the most significant bits of the
183 Composite Pixel Code, followed in order by the samples representing the next vector colors, with the
184 sample representing the vector color designated last in the Photometric Interpretation name
185 comprising the least significant bits of the Composite Pixel Code. For example, for Photometric
186 Interpretation = "RGB", the most significant "Bits Allocated" bits contain the Red sample, the next
187 "Bits Allocated" bits contain the Green sample, and the least significant "Bits Allocated" bits contain
188 the Blue sample.

189 **C.7.6.3.1.2 Photometric Interpretation**

190 The value of Photometric Interpretation (0028,0004) specifies the intended interpretation of the
191 image pixel data.

192 See PS 3.5 for restrictions imposed by compressed Transfer Syntaxes.

193 The following values are defined. Other values are permitted but the meaning is not defined by this
194 Standard.

195 **MONOCHROME1** = Pixel data represent a single monochrome image plane. The minimum sample
196 value is intended to be displayed as white after any VOI gray scale transformations have been
197 performed. See PS 3.4. This value may be used only when Samples per Pixel (0028,0002) has a
198 value of 1.

199 **MONOCHROME2** = Pixel data represent a single monochrome image plane. The minimum sample
200 value is intended to be displayed as black after any VOI gray scale transformations have been
201 performed. See PS 3.4. This value may be used only when Samples per Pixel (0028,0002) has a
202 value of 1.

203 **PALETTE COLOR** = Pixel data describe a color image with a single sample per pixel (single image
204 plane). The pixel value is used as an index into each of the Red, Blue, and Green Palette Color
205 Lookup Tables (0028,1101-1103&1201-1203). This value may be used only when Samples per Pixel
206 (0028,0002) has a value of 1. When the Photometric Interpretation is Palette Color; Red, Blue, and
207 Green Palette Color Lookup Tables shall be present.

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208 **RGB** = Pixel data represent a color image described by red, green, and blue image planes. The
 209 minimum sample value for each color plane represents minimum intensity of the color. This value
 210 may be used only when Samples per Pixel (0028,0002) has a value of 3.

211 **HSV** = Pixel data represent a color image described by hue, saturation, and value image planes.
 212 The minimum sample value for each HSV plane represents a minimum value of each vector. This
 213 value may be used only when Samples per Pixel (0028,0002) has a value of 3.

214 ~~**ARGB** = Pixel data represent a color image described by red, green, blue, and alpha image
 215 planes. The minimum sample value for each RGB plane represents minimum intensity of the
 216 color. The alpha plane is passed through Palette Color Lookup Tables. If the alpha pixel value
 217 is greater than 0, the red, green, and blue lookup table values override the red, green, and blue,
 218 pixel plane colors. This value may be used only when Samples per Pixel (0028,0002) has a
 219 value of 4. *Retired.*~~

220 **CMYK** = Pixel data represent a color image described by cyan, magenta, yellow, and black image
 221 planes. The minimum sample value for each CMYK plane represents a minimum intensity of the
 222 color. This value may be used only when Samples per Pixel (0028,0002) has a value of 4.

223 **YBR_FULL** = Pixel data represent a color image described by one luminance (Y) and two
 224 chrominance planes (C_B and C_R). This photometric interpretation may be used only when ~~S~~amples
 225 per ~~P~~ixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of
 226 color is represented by both C_B and C_R values equal to half full scale.

227 | Note: In the case where the Bits Allocated (0028,0100) has value of 8 half full scale is 128.

228 |

229 | In the case where Bits allocated (0028,0100) has a value of 8 then the following equations convert
 230 between RGB and YCB_{CR} Photometric Interpretation.

$$231 \quad Y = + .2990R + .5870G + .1140B$$

$$232 \quad C_B = - .1687R - .3313G + .5000B + 128$$

$$233 \quad C_R = + .5000R - .4187G - .0813B + 128$$

234 | Note: The above is based on CCIR Recommendation 601-2 dated 1990

235 |

236 | **YBR_FULL_422** = The same as **YBR_FULL** except that the C_B and C_R values are sampled
 237 horizontally at half the Y rate and as a result there are half as many C_B and C_R values as Y values.

238 | This ~~P~~hotometric Interpretation is only allowed with Planar Configuration (0028,0006) equal to
 239 ~~0000~~. Two Y values shall be stored followed by one C_B and one C_R value. The C_B and C_R values
 240 shall be sampled at the location of the first of the two Y values. For each Row of Pixels, the first C_B
 241 and C_R samples shall be at the location of the first Y sample. The next C_B and C_R samples shall be
 242 at the location of the third Y sample etc.

243 | Note: This subsampling is often referred to as cosited sampling.

244 |

245 | **YBR_PARTIAL_422** = The same as **YBR_FULL_422** except that:

- 246 | 1. black corresponds to $Y = 16$;
- 247 | 2. Y is restricted to 220 levels (i.e. the maximum value is 235);
- 248 | 3. C_B and C_R each has a minimum value of 16;

249 4. C_B and C_R are restricted to 225 levels (i.e. the maximum value is 240);

250 5. lack of color is represented by C_B and C_R equal to 128.

251 In the case where Bits Allocated (0028,0100) has value of 8 then the following equations convert
252 between RGB and YBR_PARTIAL_422 Photometric Interpretation

253 $Y = + .2568R + .5041G + .0979B + 16$

254 $C_B = - .1482R - .2910G + .4392B + 128$

255 $C_R = + .4392R - .3678G - .0714B + 128$

256 Note: The above is based on CCIR Recommendation 601-2 dated 1990.

257

258 **YBR_ICT = Irreversible Color Transformation:**

259 **[Editor's note: not the same as YBR_FULL because of difference in level shifting ???]**

260 Pixel data represent a color image described by one luminance (Y) and two chrominance
261 planes (C_B and C_R). This photometric interpretation may be used only when ~~Samples per~~
262 ~~P~~ixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of
263 color is represented by both C_B and C_R values equal to zero.

264 Regardless of the value of Bits Allocated (0028,0100), the following equations convert between
265 RGB and YCB_BC_R Photometric Interpretation.

266 $Y = + .29900R + .58700G + .11400B$

267 $C_B = - .16875R - .33126G + .50000B$

268 $C_R = + .50000R - .41869G - .08131B$

269 Notes: 1. The above is based on ISO/IEC 15444-1 (JPEG 2000).

270 2. In a JPEG 2000 bitstream, DC level shifting (used if the untransformed components are
271 unsigned) is applied before forward color transformation, and the transformed components
272 may be signed (unlike in JPEG ISO/IEC 10918-1).

273 3. In JPEG 2000, spatial down-sampling of the chrominance components prior to compression
274 is not performed, due to the multi-resolution decomposition approach of the compression
275 scheme.

276

277 **YUV_RCTYBR_RCT = Reversible Color Transformation:**

278 Pixel data represent a color image described by one luminance (Y) and two chrominance
279 planes (V and U). This photometric interpretation may be used only when ~~Samples per~~
280 ~~P~~ixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of color is
281 represented by both C_B and C_R . ~~V and U values equal to zero. [Editor's note: is this true ???]~~

282 Regardless of the value of Bits Allocated (0028,0100), the following equations convert between
283 RGB and YUV_RCTYBR_RCT Photometric Interpretation.

284 $Y = \lfloor R + 2G + B \rfloor / 4$

285 $C_B = B - G$

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$$\underline{C_R Y} = R - G$$

287 The following equations convert between ~~YUV_RCTYBR_RCT~~ and RGB Photometric
 288 Interpretation.

289
$$G = Y - \lfloor \underline{C_R Y} + \underline{C_B U} \rfloor / 4$$

290
$$R = \underline{C_R Y} + G$$

291
$$B = \underline{C_B U} + G$$

292 Notes: 1. The above is based on ISO/IEC 15444-1 (JPEG 2000).

293 2. In a JPEG 2000 bitstream, DC level shifting (used if the untransformed components are
 294 unsigned) is applied before forward color transformation, and the transformed components
 295 may be signed (unlike in JPEG ISO/IEC 10918-1).

296 3. This photometric interpretation is a reversible approximation to the YUV transformation used
 297 in PAL and SECAM.

298

299 **C.7.6.3.1.3 Planar Configuration**

300 Planar Configuration (0028,0006) indicates whether the color pixel data are sent color-by-plane or
 301 color-by-pixel. This Attribute shall be present if Samples per Pixel (0028,0002) has a value greater
 302 than 1. It shall not be present otherwise.

303 Enumerated Values:

304 **000** = The sample values for the first pixel are followed by the sample values for the second
 305 pixel, etc. For RGB images, this means the order of the pixel values sent shall be R1, G1,
 306 B1, R2, G2, B2, ..., etc. For HSV images, this means the order of the pixel values sent
 307 shall be H1, S1, V1, H2, S2, V2, ... etc. For ARGB images, this means the order of the
 308 pixel values sent shall be A1, R1, G1, B1, A2, R2, G2, B2, ... etc. For CMYK images, this
 309 means the order of the pixel values sent shall be C1, M1, Y1, K1, C2, M2, Y2, K2, ... etc.

310 **001** = Each color plane shall be sent contiguously. For RGB images, this means the order of
 311 the pixel values sent is R1, R2, R3, ..., G1, G2, G3, ..., B1, B2, B3, etc. For HSV images,
 312 this means the order of the pixel values sent is H1, H2, H3, ..., S1, S2, S3, ..., V1, V2, V3,
 313 etc. For ARGB images, this means the order of the pixel values sent is A1, A2, A3, ..., R1,
 314 R2, R3, ..., G1, G2, G3, ..., B1, B2, B3, etc. For CMYK images, this means the order of
 315 the pixel values sent is C1, C2, C3, ..., M1, M2, M3, ..., Y1, Y2, Y3, ..., K1, K2, K3, etc.

316 Note: **Planar Configuration (0028,0006) is not meaningful when a compression transfer syntax is used**
 317 **that involves reorganization of sample components in the compressed bit stream. In such**
 318 **cases, since the Attribute is required to be sent, then an appropriate value to use may be**
 319 **specified in the description of the Transfer Syntax in PS 3.5, though in all likelihood the value**
 320 **of the Attribute will be ignored by the receiving implementation.**

321

322

323 Add JPEG 2000 Photometric Interpretations to US Image Module C.8.5.6:

324 **C.8.5.6 US Image Module**

325 ...

326 **C.8.5.6.1.2 Photometric Interpretation**327 For US Images, Photometric Interpretation (0028,0004) is specified to use the following Defined
328 Terms:

MONOCHROME2	PALETTE COLOR	RGB
<i>ARGB (retired)</i>	YBR_FULL	YBR_FULL_422
YBR_PARTIAL_422	<u>YUV_RCTYBR_RCT</u>	<u>YBR ICT</u>

329

330 Note: It is recommended that future implementations should not use ARGB photometric interpretation.

331

332 See PS 3.5 for restrictions imposed by compressed Transfer Syntaxes.

333 ...

334 **C.8.5.6.1.12 Samples Per Pixel**335 For US Images, Samples Per Pixel (0028,0002) is specified to use the following values for specific
336 Photometric Interpretations:337
338 **Table C.8-19**
US SAMPLES PER PIXEL

Photometric Interpretation	Samples Per Pixel Value
MONOCHROME2	0001H
RGB	0003H
YBR_FULL	0003H
YBR_FULL_422	0003H
YBR_PARTIAL_422	0003H
<u>YUV_RCTYBR_RCT</u>	<u>0003H</u>
<u>YBR ICT</u>	<u>0003H</u>
PALETTE COLOR	0001H

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340 **C.8.5.6.1.13 Bits Allocated**

341 For US Images, Bits Allocated (0028,0100) is specified to use the following values for specific
 342 Photometric Interpretations:

343 **Table C.8-20**
 344 **US BITS ALLOCATED**

Photometric Interpretation	Bits Allocated Value
MONOCHROME2	0008H
RGB	0008H
YBR_FULL	0008H
YBR_FULL_422	0008H
YBR_PARTIAL_422	0008H
YUV_RCTYBR_RCT	0008H
YBR_ICT	0008H
PALETTE COLOR	0008H - 8 bit palette, or 0010H 16 - 16 bit palette

345

346 **C.8.5.6.1.14 Bits Stored**

347 For US Images, Bits Stored (0028,0101) is specified to use the following values for specific
 348 Photometric Interpretations:

349 **Table C.8-21**
 350 **US BITS STORED**

Photometric Interpretation	Bits Stored Value
MONOCHROME2	0008H
RGB	0008H
YBR_FULL	0008H
YBR_FULL_422	0008H
YBR_PARTIAL_422	0008H
YUV_RCTYBR_RCT	0008H
YBR_ICT	0008H
PALETTE COLOR	0008H - 8 bit palette, or 0010H 16 - 16 bit palette

351

352 **C.8.5.6.1.15 High Bit**

353 For US Images, High Bit (0028,0102) is specified to use the following values for specific Photometric
 354 Interpretations:

355
356**Table C.8-22**
US HIGH BIT

Photometric Interpretation	High Bit Value
MONOCHROME2	0007H
RGB	0007H
YBR_FULL	0007H
YBR_FULL_422	0007H
YBR_PARTIAL_422	0007H
<u>YUV_RCTYBR_RCT</u>	<u>0007H</u>
<u>YBR_ICT</u>	<u>0007H</u>
PALETTE COLOR	0007H - 8 bit palette, or 000FH 15 - 16 bit palette

357

C.8.5.6.1.16 Planar Configuration

For US Images, Planar Configuration (0028,0006) is specified to use the following values for specific Photometric Interpretations:

Table C.8-23
US PLANAR CONFIGURATION

Photometric Interpretation	Planar Configuration Value
RGB	0000H - color-by-pixel, or 0001H - color-by-plane
YBR_FULL	0001H
YBR_FULL_422	0000H
YBR_PARTIAL_422	0000H
<u>YUV_RCTYBR_RCT</u>	<u>0000H</u>
<u>YBR_ICT</u>	<u>0000H</u>

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364

365 *Add JPEG 2000 Photometric Interpretations to VL Image Module C.8.12.1:*

C.8.12.1 VL Image Module

367 ...

C.8.12.1.1 VL Image Module Attribute Descriptions**C.8.12.1.1.1 Photometric Interpretation**

370 The Enumerated Values of Photometric Interpretation (0028,0004) shall:

371 MONOCHROME2

372 RGB

373 YBR_FULL_422

374 **YUV_RCTYBR_RCT**

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375 **YBR_ICT**

376

377 **C.8.12.1.1.2 Bits Allocated, Bits Stored, and High Bit**378 The Enumerated Value of Bits Allocated (0028,0100) shall be 8; the Enumerated Value of Bits
379 Stored (0028,0101) shall be 8; and the Enumerated Value of High Bit (0028,0102) shall be 7.380 **C.8.12.1.1.3 Pixel Representation**381 The Enumerated Value of Pixel Representation (0028,0103) shall be **0000H**.382 **Note: A value of 0000H signifies an unsigned integer value.**

383

384 **C.8.12.1.1.4 Samples per Pixel**385 The Enumerated Values of Samples per Pixel (0028,0002) shall be as follows: If the value of
386 Photometric Interpretation (0028,0004) is MONOCHROME2, then the Enumerated Value of
387 Samples per Pixel (0028,0002) shall be one (1). If the value of Photometric Interpretation
388 (0028,0004) is RGB or YBR_FULL_422 or **YUV_RCTYBR_RCT** or **YBR_ICT**, then the Enumerated
389 Value of Samples per Pixel (0028,0002) shall be three (3).390 **C.8.12.1.1.5 Planar Configuration**391 If present, the Enumerated Value of Planar Configuration (0028,0006) shall be **0000H**. This value
392 shall be present if Samples per Pixel (0028,0002) has a value greater than 1.

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401 **Changes to**

402 **NEMA Standards Publication PS 3.5-2000**

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404 *Digital Imaging and Communications in Medicine (DICOM)*

405 *Part 5: Data Structures and Encoding*

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406 **Add JPEG 2000 to Section 2:**407 **Section 2 Normative references**

408 The following standards contain provisions that, through references in this text, constitute provisions
 409 of this standard. At the time of publication, the editions indicated were valid. All standards are subject
 410 to revision, and parties to agreements based on this standard are encouraged to investigate the
 411 possibilities of applying the most recent editions of the standards indicated below.

412 ...

413 ISO/IS 10918-1 JPEG Standard for digital compression and encoding of continuous-tone
 414 still images. Part 1—Requirements and implementation guidelines

415 ISO/IS 10918-2 JPEG Standard for digital compression and encoding of continuous-tone
 416 still images. Part 2—Testing

417 ISO/IS 14495-1 Lossless and near-lossless coding of continuous tone still images (JPEG-
 418 LS)

419 **ISO/IS 15444-1 JPEG 2000 Image Coding System**

420 ...

421

422 **Add JPEG 2000 to Section 8:**

423

424 **Section 8 Encoding of Pixel, Overlay and Waveform Data**

425 ...

426

427 **8.2 NATIVE OR ENCAPSULATED FORMAT ENCODING**

428 Pixel data conveyed in the Pixel Data Element (7FE0,0010) may be sent either in a Native
 429 (uncompressed) Format or in an Encapsulated Format (e.g. compressed) defined outside the
 430 DICOM standard.

431 If Pixel Data is sent in a Native Format, the Value Representation OW is most often required. The
 432 Value Representation OB may also be used for Pixel Data in cases where Bits Allocated has a value
 433 less than or equal to 8, but only with Transfer Syntaxes where the Value Representation is explicitly
 434 conveyed (see Annex A).

435 Note: The DICOM default Transfer Syntax (Implicit VR LittleEndian) does not explicitly convey Value
 436 Representation and therefore the VR of OB may not be used for Pixel Data when using the default
 437 Transfer Syntax.

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438 Native format Pixel Cells are encoded as the direct concatenation of the bits of each Pixel Cell,
 439 where the most significant bit of a Pixel Cell is immediately followed by the least significant bit of the
 440 next Pixel Cell. The number of bits of each Pixel Cell is defined by the Bits Allocated (0028,0100)
 441 Data Element Value. When a Pixel Cell crosses a word boundary in the OW case, or a byte
 442 boundary in the OB case, it shall continue to be encoded, least significant bit to most significant bit,
 443 in the next word, or byte, respectively (see Annex D). For Pixel Data encoded with the Value
 444 Representation OW, the byte ordering of the resulting 2-byte words is defined by the Little Endian or
 445 Big Endian Transfer Syntaxes negotiated at the Association Establishment (see Annex A).

446 Notes: 1. For Pixel Data encoded with the Value Representation OB, the Pixel Data encoding is unaffected
 447 by Little Endian or Big Endian byte ordering.
 448
 449 2. If encoding Pixel Data with a Value for Bits Allocated (0028,0100) not equal to 16 be sure to read
 450 and understand Annex D.

451
 452 If sent in an Encapsulated Format (i.e. other than the Native Format) the Value Representation OB is
 453 used. The Pixel Cells are encoded according to the encoding process defined by one of the
 454 negotiated Transfer Syntaxes (see Annex A). The encapsulated pixel stream of encoded pixel data
 455 is segmented in one or more Fragments which convey their explicit length. The sequence of
 456 Fragments of the encapsulated pixel stream is terminated by a delimiter, thus allowing the support of
 457 encoding processes where the resulting length of the entire pixel stream is not known until it is
 458 entirely encoded. This Encapsulated Format supports both Single-Frame and Multi-Frame images
 459 (as defined in PS 3.3).

460 8.2.1 JPEG IMAGE COMPRESSION

461 DICOM provides a mechanism for supporting the use of JPEG Image Compression through the
 462 Encapsulated Format (see PS 3.3). Annex A defines a number of Transfer Syntaxes which reference
 463 the JPEG Standard and provide a number of lossless (bit preserving) and lossy compression
 464 schemes.

465 Note: The context where the usage of lossy compression of medical images is clinically acceptable is
 466 beyond the scope of the DICOM Standard. The policies associated with the selection of appropriate
 467 compression parameters (e.g. compression ratio) for JPEG lossy compression is also beyond the
 468 scope of this standard.

469
 470 In order to facilitate interoperability of implementations conforming to the DICOM Standard which
 471 elect to use one or more of the Transfer Syntaxes for JPEG Image Compression, the following policy
 472 is specified:

- 473 — Any implementation which conforms to the DICOM Standard and has elected to support
 474 any one of the Transfer Syntaxes for lossless JPEG Image Compression, shall support
 475 the following lossless compression: The subset (first-order horizontal prediction [Selection
 476 Value 1] of JPEG Process 14 (DPCM, non-hierarchical with Huffman coding) (see Annex
 477 F).
- 478 — Any implementation which conforms to the DICOM Standard and has elected to support
 479 any one of the Transfer Syntaxes for 8-bit lossy JPEG Image Compression, shall support
 480 the JPEG Baseline Compression (coding Process 1).
- 481 — Any implementation which conforms to the DICOM Standard and has elected to support
 482 any one of the Transfer Syntaxes for 12-bit lossy JPEG Image Compression, shall support
 483 the JPEG Compression Process 4.

484 Note: The DICOM conformance statement shall differentiate whether or not the implementation is capable
 485 of simply receiving or receiving and processing JPEG encoded images (see PS 3.2).

486
 487 The use of the DICOM Encapsulated Format to support JPEG Compressed Pixel Data requires that
 488 the Data Elements which are related to the Pixel Data encoding (e.g. Photometric Interpretation,

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489 Samples per Pixel, Planar Configuration, Bits Allocated, Bits Stored, High Bit, Pixel Representation,
 490 Rows, Columns, etc.) shall contain values which are consistent with the characteristics of the
 491 compressed data stream . The Pixel Data characteristics included in the JPEG Interchange Format
 492 shall be used to decode the compressed data stream.

- 493 Notes: 1. These requirements were formerly specified in terms of the "uncompressed pixel data from which
 494 the compressed data stream was derived". However, since the form of the "original" uncompressed
 495 data stream could vary between different implementations, this requirement is now specified in terms
 496 of consistency with what is encapsulated.
 497 When decompressing, should the characteristics explicitly specified in the compressed data stream
 498 (e.g. spatial subsampling or number of components or planar configuration) be inconsistent with those
 499 specified in the DICOM Data Elements, those explicitly specified in the compressed data stream
 500 should be used to control the decompression. The DICOM data elements, if inconsistent, can be
 501 regarded as suggestions as to the form in which an uncompressed data set might be encoded.
 502 2. Those characteristics not explicitly specified in the compressed data stream (e.g. color space which
 503 is not specified in the JPEG Interchange Format), or implied by the definition of the compression
 504 scheme (e.g. always unsigned in JPEG), can therefore be determined from the DICOM Data Element in
 505 the enclosing data set. For example a Photometric Interpretation of "YBR FULL 422" would describe
 506 the color space that is commonly used to lossy compress images using JPEG. It is unusual to use an
 507 RGB color space for lossy compression, since no advantage is taken of correlation between the red,
 508 green and blue components (e.g. of luminance), and poor compression is achieved.
 509 3. Should the compression process be incapable of encoding a particular form of pixel data
 510 representation (e.g. JPEG cannot encode signed integers, only unsigned integers), then ideally only
 511 the appropriate form should be "fed" into the compression process. However, for certain
 512 characteristics described in DICOM Data Elements but not explicitly described in the compressed
 513 data stream (such as Pixel Representation), then the DICOM Data Element should be considered to
 514 describe what has been compressed (e.g. the pixel data really is to be interpreted as signed if Pixel
 515 Representation so specifies).
 516 4. DICOM Data Elements should not describe characteristics that are beyond the capability of the
 517 compression scheme used. For example, JPEG lossy processes are limited to 12 bits, hence the value
 518 of Bits Stored should be 12 or less. Bits Allocated is irrelevant, and is likely to be constrained by the
 519 Information Object Definition in PS 3.3 to values of 8 or 16. Also, JPEG compressed data streams are
 520 always color-by-pixel and should be specified as such (a decoder can essentially ignore this element
 521 however as the value for JPEG compressed data is already known).

523 **8.2.2 Run Length Encoding Compression**

524 DICOM provides a mechanism for supporting the use of Run Length Encoding (RLE) Compression
 525 which is a byte oriented lossless compression scheme through the encapsulated Format (see PS 3.3
 526 of this Standard). Annex G defines RLE Compression and its Transfer Syntax.

- 527 Note: The RLE Compression algorithm described in Annex G is the compression used in the TIFF 6.0
 528 specification known as the "PackBits" scheme.

530 The use of the DICOM Encapsulated Format to support RLE Compressed Pixel Data requires that
 531 the Data Elements which are related to the Pixel Data encoding (e.g. Photometric Interpretation,
 532 Samples per Pixel, Planar Configuration, Bits Allocated, Bits Stored, High Bit, Pixel Representation,
 533 Rows, Columns, etc.) shall contain values which are consistent with the compressed data.

- 534 Notes: 1. These requirements were formerly specified in terms of the "uncompressed pixel data from which
 535 the compressed data was derived". However, since the form of the "original" uncompressed data
 536 stream could vary between different implementations, this requirement is now specified in terms of
 537 consistency with what is encapsulated.
 538 2. Those characteristics not implied by the definition of the compression scheme (e.g. always color-
 539 by-plane in RLE), can therefore be determined from the DICOM Data Element in the enclosing data
 540 set. For example a Photometric Interpretation of "YBR FULL" would describe the color space that is
 541 commonly used to losslessly compress images using RLE. It is unusual to use an RGB color space for
 542 RLE compression, since no advantage is taken of correlation between the red, green and blue
 543 components (e.g. of luminance), and poor compression is achieved (note however that the conversion
 544 from RGB to YBR FULL is itself lossy. A new photometric interpretation may be proposed in the future
 545 which allows lossless conversion from RGB and also results in better RLE compression ratios).

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546 3. DICOM Data Elements should not describe characteristics that are beyond the capability of the
 547 compression scheme used. For example, RLE compressed data streams (using the algorithm mandated
 548 in the DICOM Standard) are always color-by-plane.

549

550 **8.2.3 JPEG-LS IMAGE COMPRESSION**

551 DICOM provides a mechanism for supporting the use of JPEG-LS Image Compression through the
 552 Encapsulated Format (see PS 3.3). Annex A defines a number of Transfer Syntaxes which reference
 553 the JPEG-LS Standard and provide a number of lossless (bit preserving) and lossy (near-lossless)
 554 compression schemes.

555 Note: The context where the usage of lossy (near-lossless) compression of medical images is clinically
 556 acceptable is beyond the scope of the DICOM Standard. The policies associated with the selection
 557 of appropriate compression parameters (e.g. compression ratio) for JPEG-LS lossy (near-lossless)
 558 compression is also beyond the scope of this standard.

559

560 The use of the DICOM Encapsulated Format to support JPEG-LS Compressed Pixel Data requires
 561 that the Data Elements which are related to the Pixel Data encoding (e.g. Photometric Interpretation,
 562 Samples per Pixel, Planar Configuration, Bits Allocated, Bits Stored, High Bit, Pixel Representation,
 563 Rows, Columns, etc.) shall contain values which are consistent with the characteristics of the
 564 compressed data stream. The Pixel Data characteristics included in the JPEG-LS Interchange
 565 Format shall be used to decode the compressed data stream.

566 Note: See also the notes in section 8.2.1.

567

568 **8.2.4 JPEG 2000 IMAGE COMPRESSION**

569 **DICOM provides a mechanism for supporting the use of JPEG 2000 Image Compression**
 570 **through the Encapsulated Format (see PS 3.3). Annex A defines a number of Transfer Syntaxes**
 571 **which reference the JPEG 2000 Standard and provide lossless (bit preserving) and lossy**
 572 **compression schemes.**

573 Note: **The context where the usage of lossy compression of medical images is clinically acceptable is**
 574 **beyond the scope of the DICOM Standard. The policies associated with the selection of**
 575 **appropriate compression parameters (e.g. compression ratio) for JPEG 2000 lossy**
 576 **compression is also beyond the scope of this standard.**

577

578 **The use of the DICOM Encapsulated Format to support JPEG 2000 Compressed Pixel Data**
 579 **requires that the Data Elements which are related to the Pixel Data encoding (e.g. Photometric**
 580 **Interpretation, Samples per Pixel, Planar Configuration, Bits Allocated, Bits Stored, High Bit,**
 581 **Pixel Representation, Rows, Columns, etc.) shall contain values which are consistent with the**
 582 **characteristics of the compressed data stream. The Pixel Data characteristics included in the**
 583 **JPEG 2000 bit stream shall be used to decode the compressed data stream.**

584 Note: **These requirements are specified in terms of consistency with what is encapsulated, rather**
 585 **than in terms of the uncompressed pixel data from which the compressed data stream may have**
 586 **been derived.**

587 **When decompressing, should the characteristics explicitly specified in the compressed data**
 588 **stream be inconsistent with those specified in the DICOM Data Elements, those explicitly**
 589 **specified in the compressed data stream should be used to control the decompression. The**
 590 **DICOM data elements, if inconsistent, can be regarded as suggestions as to the form in which**
 591 **an uncompressed data set might be encoded.**

592

593 **The JPEG 2000 bit stream specifies whether or not a reversible or irreversible multi-component**
 594 **(color) transformation, if any, has been applied. If no multi-component transformation has been**
 595 **applied, then the components shall correspond to those specified by the DICOM Attribute**
 596 **Photometric Interpretation. If the JPEG 2000 reversible multi-component transformation has**

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597 | **been applied then the DICOM Attribute Photometric Interpretation shall be YUV_RCTYBR_RCT. If**
 598 | **the JPEG 2000 irreversible multi-component transformation has been applied then the DICOM**
 599 | **Attribute Photometric Interpretation shall be YBR_ICT.**

600 | **Notes:** 1. For example, single component may be present, and the Photometric Interpretation may be
 601 | **MONOCHROME2.**
 602 | 2. Though it would be unusual, would not take advantage of correlation between the red, green
 603 | and blue components, and would not achieve effective compression, a Photometric
 604 | Interpretation of RGB could be specified as long as no multi-component transformation was
 605 | specified by the JPEG 2000 bit stream.
 606 | 3. Despite the application of a multi-component color transformation and its reflection in the
 607 | Photometric Interpretation attribute, the “color space” remains undefined. There is currently no
 608 | means of conveying “standard color spaces” either by fixed values (such as sRGB) or by ICC
 609 | profiles. Note in particular that the JP2 file header is not sent in the JPEG 2000 bitstream that is
 610 | encapsulated in DICOM.

611 |
 612 | **The JPEG 2000 bitstream is capable of encoding both signed and unsigned pixel values, hence**
 613 | **the value of Pixel Representation may be either 0 or 1 depending on what has been encoded**
 614 | **(as specified in the SIZ marker segment in the precision and sign of component parameter).**

615 | **[Editor's note: what about when this varies by component ?]**

616 | **The value of Planar Configuration is irrelevant since the manner of encoding components is**
 617 | **specified in the JPEG 2000 standard, hence it shall be set to 0.**

618 |

619 | Add JPEG 2000 default requirements to Section 10:

620 |

Section 10 Transfer Syntax

621 | A Transfer Syntax is a set of encoding rules able to unambiguously represent one or more Abstract
 622 | Syntaxes. In particular, it allows communicating Application Entities to negotiate common encoding
 623 | techniques they both support (e.g., byte ordering, compression, etc.). A Transfer Syntax is an
 624 | attribute of a Presentation Context, one or more of which are negotiated at the establishment of an
 625 | Association between DICOM Application Entities. This Association negotiation is specified in PS 3.8
 626 | and discussed in PS 3.7.

627 | The selection of a Transfer Syntax applies to the encoding rules for the Data Set portion of a DICOM
 628 | Message only. All DICOM Standard and Private Transfer Syntaxes implicitly specify a fixed encoding
 629 | for the Command Set portion of a DICOM Message as Specified in PS 3.7.

630 | This part of the DICOM Standard defines standard DICOM Transfer Syntaxes and assigns a unique
 631 | Transfer Syntax Name to each one. The standard DICOM Transfer Syntaxes are specified in Annex
 632 | A. The DICOM notation for Transfer Syntax names is the notation used for UIDs (see Section 9).

633 | The organization responsible for the definition and registration of DICOM Transfer Syntaxes is
 634 | NEMA. NEMA guarantees uniqueness for all DICOM Transfer Syntax Names.

635 | Privately defined Transfer Syntax Names may also be used; however, they will not be registered by
 636 | NEMA. Organizations that define private Transfer Syntax Names shall follow the registration process
 637 | defined in Section 9.2.

638 **10.1 DICOM DEFAULT TRANSFER SYNTAX**

639 DICOM defines a default Transfer Syntax, the DICOM Implicit VR Little Endian Transfer Syntax (UID
 640 = "1.2.840.10008.1.2"), that shall be supported by every conformant DICOM Implementation. This
 641 implies that:

- 642 a) If an Application Entity issues an A-ASSOCIATE request, it shall offer the DICOM Implicit
 643 VR Little Endian Transfer Syntax in at least one of the Presentation Contexts associated
 644 with each offered Abstract Syntax.

645 Note: Offering Abstract Syntax (AS1) in two Presentation Contexts with Transfer Syntaxes (TS1) and (TS2)
 646 is not valid, but offering AS1-TS1, AS1-TS2 and AS1-TSD is valid because the DICOM Default Little
 647 Endian Transfer Syntax (TSD) is present in at least one of the Presentation Contexts which are based
 648 on Abstract Syntax (AS1).

- 649 b) If an Application Entity receives an A-ASSOCIATE indication corresponding to a request
 650 which follows the requirements specified in Section 10.1 a), every Presentation Context
 651 related to a given Abstract Syntax cannot be rejected in an A-ASSOCIATE response for
 652 the reason that none of the Transfer Syntaxes are supported.

653 Both of these requirements, a) and b), are waived when the Application Entity sending the pixel data
 654 has only access to the pixel data in lossy compressed form.

655 Note: In other words, every sending AE is required to be able to convert any dataset it is going to
 656 transmit into the Default Transfer Syntax, regardless of the form in which it originally received
 657 or stored the data set, except in the single case of when it received it in a lossy compressed
 658 form. In that exceptional case, the sending AE is permitted to propose only the lossy
 659 compressed Transfer Syntax appropriate to the lossy form that was received.

660 In particular, this waiver does not apply to data sets received in a lossless compressed form,
 661 which means that any AE receiving a data set in a lossless compressed Transfer Syntax that
 662 needs to re-send the data set is required to be able to decompress it in order to support (at
 663 least) the default Transfer Syntax.

664 **10.2 TRANSFER SYNTAX FOR A DICOM DEFAULT OF LOSSLESS JPEG COMPRESSION**

665 DICOM defines a default for lossless JPEG Image Compression, which uses a subset of coding
 666 Process 14 with a first-order prediction (Selection Value 1). It is identified by Transfer Syntax UID =
 667 "1.2.840.10008.1.2.4.70" and shall be supported by every DICOM implementation that chooses to
 668 support one or more of the lossless JPEG compression processes. This implies that:

- 670 a) If an Application Entity issues an A-ASSOCIATE request where any offered Abstract
 671 Syntaxes is associated in one or more Presentation Context with a JPEG lossless
 672 compression Transfer Syntax, at least one of the Presentation Contexts which include this
 673 Abstract Syntax, shall include the DICOM Default Lossless JPEG Compression Transfer
 674 Syntax and the DICOM Default Transfer Syntax (uncompressed).

675 Note: Offering Abstract Syntax (AS1) in two Presentation Contexts with Transfer Syntaxes JPEG lossless
 676 (JL1) and (JL2) is not valid, but offering AS1-JL1, AS1-JL2, AS1-TSD, and AS1-JLD is valid because
 677 the DICOM Default JPEG Lossless Transfer Syntax (JLD) and the DICOM Default Transfer Syntax
 678 (TSD) are present in at least one of the Presentation Contexts which are based on Abstract Syntax
 679 (AS1).

- 680 b) If an Application Entity that supports one or more lossless JPEG Transfer Syntax receives
 681 an A-ASSOCIATE indication corresponding to a request which follows the requirements
 682 specified in Section 10.2 a), every Presentation Context related to a given Abstract Syntax
 683 cannot be rejected in an A-ASSOCIATE response for the reason that the DICOM Default
 684 lossless JPEG Transfer Syntax is not supported.

685 **10.3 TRANSFER SYNTAXES FOR A DICOM DEFAULTS OF LOSSY JPEG COMPRESSION**

686 DICOM defines defaults for Lossy JPEG Image Compression, one for 8-bit images and the other for
 687 12-bit images. JPEG coding Process 1 (identified by Transfer Syntax UID =

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688 "1.2.840.10008.1.2.4.50") is used for 8-bit images. JPEG coding Process 4 (identified by Transfer
 689 Syntax UID = "1.2.840.10008.1.2.4.51") is used for 12-bit images. This implies that:

690 a) If an Application Entity issues an A-ASSOCIATE request where any offered Abstract
 691 Syntaxes is associated in one or more Presentation Context(s) with a JPEG lossy
 692 compression Transfer Syntax, at least one of the Presentation Contexts which include this
 693 Abstract Syntax, shall include the appropriate DICOM Default Lossy JPEG Compression
 694 Transfer Syntax.

695 Note: 1. Offering Abstract Syntax (AS1) in two Presentation Contexts with Transfer Syntaxes JPEG lossy
 696 (JL1) and (JL2) is not valid, but offering AS1-JL1, AS1-JL2 and AS1-JLD is valid because the DICOM
 697 Default JPEG Lossy Transfer Syntax (JLD) is present in at least one of the Presentation Contexts
 698 which are based on Abstract Syntax (AS1).
 699 2. The DICOM Default Transfer Syntax (uncompressed) may be offered if the sender has access to
 700 the original pixel data in an uncompressed or lossless compressed form.

701 b) If an Application Entity that supports one or more Lossy JPEG Transfer Syntaxes receives
 702 an A-ASSOCIATE indication corresponding to a request which follows the requirements
 703 specified in Section 10.3 a), every Presentation Context related to a given Abstract Syntax
 704 cannot be rejected in an A-ASSOCIATE response for the reason that the DICOM Default
 705 lossy JPEG Transfer Syntax is not supported.

706 **10.4 TRANSFER SYNTAX FOR DICOM RLE COMPRESSION**

707 DICOM defines the RLE Compression (see Annex G). This implies that:

708 a) If an Application Entity issues an A-ASSOCIATE request where any offered Abstract
 709 Syntaxes is associated in one or more Presentation Context(s) with RLE compression
 710 Transfer Syntax, at least one of the Presentation Contexts which include this Abstract
 711 Syntax, shall include the DICOM Default Transfer Syntax (uncompressed).

712

713 **10.5 TRANSFER SYNTAX FOR A DICOM DEFAULT OF LOSSLESS AND LOSSY (NEAR- 714 LOSSLESS) JPEG-LS COMPRESSION**

715 One Transfer Syntax is specified for JPEG-LS Lossless Image Compression, and one Transfer
 716 Syntax is specified for JPEG-LS Lossy (Near-Lossless) Image Compression. The JPEG-LS Lossless
 717 Transfer Syntax shall be supported as a baseline if the JPEG-LS Lossy (Near-Lossless) Transfer
 718 Syntax is supported.

719 **10.6 TRANSFER SYNTAX FOR A DICOM DEFAULT FOR JPEG 2000 COMPRESSION**

720 **One Transfer Syntax is specified for JPEG 2000 Lossless Image Compression, and one
 721 Transfer Syntax is specified for JPEG 2000 Lossy Image Compression. Any implementation
 722 that supports either transfer syntax shall also support the other.**

723 Notes: 1. All JPEG 2000 codecs are required by ISO/IEC 15444-1 to support both reversible and
 724 irreversible wavelet and multi-component transformations. The reason for specifying two
 725 separate Transfer Syntaxes in DICOM is to allow an application to require-request the transfer
 726 of images in a lossless manner when necessary/possible.
 727 2. No baseline using other compression schemes is required.
 728 3. The waiver of the requirement in Section 10.1 to support the DICOM Default Transfer
 729 Syntax still applies when the Application Entity sending the pixel data has only access to the
 730 pixel data in lossy compressed form.

731

732 *Add JPEG 2000 requirements to Annex A:*

733
734
735

**Annex A
(Normative)
Transfer Syntax Specifications**

736 ...

737 **A.4 TRANSFER SYNTAXES FOR ENCAPSULATION OF ENCODED PIXEL DATA**

738 These Transfer Syntaxes apply to the encoding of the entire DICOM Data Set, even though the
739 image Pixel Data (7FE0,0010) portion of the DICOM Data Set is the only portion that is encoded by
740 an encapsulated format. This implies that when a DICOM Message is being encoded according to
741 an encapsulation Transfer Syntax the following requirements shall be met:

- 742 a) The Data Elements contained in the Data Set structure shall be encoded with Explicit VR
743 (with a VR Field) as specified in Section 7.1.2.
- 744 b) The encoding of the overall Data Set structure (Data Element Tags, Value Length, etc.)
745 shall be in Little Endian as specified in Section 7.3.
- 746 c) The encoding of the Data Elements of the Data Set shall be as follows according to their
747 Value Representations:
 - 748 — For all Value Representations defined in this part of the DICOM Standard, except for the
749 Value Representations OB and OW, the encoding shall be in Little Endian as specified in
750 Section 7.3.
 - 751 — For the Value Representations OB and OW, the encoding shall meet the following
752 specification depending on the Data Element Tag:
 - 753 — Data Element (7FE0,0010) Pixel Data has the Value Representation OB and is a
754 sequence of bytes resulting from one of the encoding processes. It contains the
755 encoded pixel data stream fragmented into one or more Item(s). This Pixel Data
756 Stream may represent a Single or Multi-frame Image. See Tables A.4-1 and A.4-2:
 - 757 — The Length of the Data Element (7FE0,0010) shall be set to the Value for
758 Undefined Length (FFFFFFFH).
 - 759 — Each Data Stream Fragment encoded according to the specific encoding
760 process shall be encapsulated as a DICOM Item with a specific Data Element
761 Tag of Value (FFFE,E000). The Item Tag is followed by a 4 byte Item Length
762 field encoding the explicit number of bytes of the Item.
 - 763 — All items containing an encoded fragment shall be made of an even number of
764 bytes greater or equal to two. The last fragment of a frame may be padded, if
765 necessary, to meet the sequence item format requirements of the DICOM
766 Standard.

767 Notes: 1. Any necessary padding may be added in the JPEG or JPEG-LS compressed data stream as per ISO
768 10918-1 and ISO 14495-1 such that the End of Image (EOI) marker ends on an even byte boundary, or
769 may be appended after the EOI marker, depending on the implementation.
770 2. ISO 10918-1 and ISO 14495-1 define the ability to add any number of padding bytes FFH before
771 any marker (all of which also begin with FFH). It is strongly recommended that FFH padding bytes not
772 be added before the Start of Image (SOI) marker.

- 773
- 774 — The first Item in the Sequence of Items before the encoded Pixel Data Stream
775 shall be a Basic Offset Table item. The Basic Offset Table Item Value, however,
776 is not required to be present:

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- 777 — When the Item Value is not present, the Item Length shall be zero (00000000H)
 778 (see Table A.4-1).
- 779 — When the Item Value is present, the Basic Offset Table Item Value shall contain
 780 concatenated 32-bit unsigned integer values that are byte offsets to the first
 781 byte of the Item Tag of the first fragment for each frame in the Sequence of
 782 Items. These offsets are measured from the first byte of the first Item Tag
 783 following the Basic Offset Table item (See Table A.4-2).

784
 785 Note: For a Multi-Frame Image containing only one frame or a Single Frame Image, the Basic Offset Table
 786 Item Value may be present or not. If present it will contain a single 00000000H value.

- 787
 788 — This Sequence of Items is terminated by a Sequence Delimiter Item with the
 789 Tag (FFFE,E0DD) and an Item Length Field of Value (00000000H) (i.e., no
 790 Value Field shall be present).
- 791 — Data Element (60xx,3000) Overlay Data
 792 — shall have the Value Representation OB or OW and shall be encoded in Little
 793 Endian.
- 794 — Data Element (50xx,3000) for Curve Data has the Value Representation specified in
 795 its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the
 796 enumerated list of allowable VRs. The component points shall be encoded in Little
 797 Endian.
- 798 — Data Element (5400,1010) Waveform Data has the Value Representation specified
 799 in its Explicit VR Field. The component points shall be encoded in Little Endian.
- 800 — Data Element (50xx,200C) Audio Sample Data has the Value Representation OB
 801 when Audio Sample Format (50xx,2002) specifies 8-bit values, and OW encoded in
 802 Little Endian when 16 bit values are specified. See the specification of the Audio
 803 Module in PS 3.3.
- 804 — Data Elements (0028,1201), (0028,1202), (0028,1203) Red, Green, Blue Palette
 805 Lookup Table Data have the Value Representation OW and shall be encoded in
 806 Little Endian.

807 Note: Previous versions of the Standard either did not specify the encoding of these Data
 808 Elements in this Part, but specified a VR of US or SS in PS 3.6 (1993), or specified OW
 809 in this Part but a VR of US, SS or OW in PS 3.6 (1996). The actual encoding of the
 810 values and their byte order would be identical in each case, though the explicitly
 811 encoded VR field would be different. However, an explicit VR of US or SS cannot be
 812 used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

- 813 — Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette
 814 Lookup Table Descriptor have the Value Representation SS or US (depending on
 815 rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first
 816 and third values are always interpreted as unsigned, regardless of the Value
 817 Representation.
- 818 — Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green,
 819 Blue Palette Color Lookup table Data have the Value Representation OW and shall
 820 be encoded in Little Endian.
- 821 — Data Element (0028,3006) Lookup Table Data has the Value Representation US, SS
 822 or OW and shall be encoded in Little Endian.

823 Note: Previous versions of the Standard did not specify the encoding of these Data Elements
 824 in this Part, but specified a VR of US or SS in PS 3.6 (1998). However, an explicit VR of
 825 US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is
 826 restricted to 16 bits. Hence a VR of OW has been added. The actual encoding of the
 827 values and their byte order would be identical in each case, though the explicitly
 828 encoded VR field would be different.

- 829 — Data Element (0028,3002) Lookup Table Descriptor has the Value Representation
 830 SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded

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831 in Little Endian. The first and third values are always interpreted as unsigned,
832 regardless of the Value Representation.

833
834 Note: For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little
835 Endian or Big Endian byte ordering.

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Table A.4-1
EXAMPLE FOR ELEMENTS OF AN ENCODED SINGLE-FRAME IMAGE DEFINED AS A SEQUENCE OF THREE FRAGMENTS WITHOUT BASIC OFFSET TABLE ITEM VALUE

Pixel Data Element Tag	Value Representation		Data Element Length	Data Element				
(7FE0, 0010) with VR of OB	OB	0000H Reserve d	FFFF FFFFH undefined length	Basic Offset Table with NO Item Value		First Fragment (Single Frame) of Pixel Data		
4 bytes	2 bytes	2 bytes	4 bytes	Item Tag (FFFE, E000)	Item Length 0000 0000H	Item Tag (FFFE, E000)	Item Length 0000 04C6H	Item Value Compressed Fragment
				4 bytes	4 bytes	4 bytes	4 bytes	04C6H bytes

839

Data Element Continued							
Second Fragment (Single Frame) of Pixel Data			Third Fragment (Single Frame) of Pixel Data			Sequence Delimiter Item	
Item Tag	Item Length	Item Value	Item Tag	Item Length	Item Value	Sequence Delim. Tag	Item Length
(FFFE, E000)	0000 024AH	Compressed Fragment	(FFFE, E000)	0000 0628H	Compressed Fragment	(FFFE, E0DD)	0000 000H
4 bytes	4 bytes	024AH bytes	4 bytes	4 bytes	0628H bytes	4 bytes	4 bytes

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Table A.4-2
EXAMPLES OF ELEMENTS FOR AN ENCODED TWO-FRAME IMAGE DEFINED AS A SEQUENCE OF THREE FRAGMENTS WITH BASIC TABLE ITEM VALUES

Pixel Data Element Tag	Value Representation		Data Element Length	Data Element					
(7FE0, 0010) with VR of OB	OB	0000H Reserve d	FFFF FFFFH undefined length	Basic Offset Table with Item Value			First Fragment (Frame 1) of Pixel Data		
				Item Tag (FFFE, E000)	Item Length 0000 0008H	Item Value 0000 0000H 0000 0646H	Item Tag (FFFE, E000)	Item Length 0000 02C8H	Item Value Compressed Fragment
4 bytes	2 bytes	2 bytes	4 bytes	4 bytes	4 bytes	0008H bytes	4 bytes	4 bytes	02C8H bytes

844

Data Element Continued							
Second Fragment (Frame 1) of Pixel Data			Third Fragment (Frame 2) of Pixel Data			Sequence Delimiter Item	
Item Tag	Item Length	Item Value	Item Tag	Item Length	Item Value	Sequence Delimiter Tag	Item Length
(FFFE, E000)	0000 036EH	Compressed Fragment	(FFFE, E000)	0000 0BC8H	Compressed Fragment	(FFFE, E0DD)	0000 0000H
4 bytes	4 bytes	036EH bytes	4 bytes	4 bytes	0BC8H bytes	4 bytes	4 bytes

845

A.4.1 JPEG IMAGE COMPRESSION

The International Standards Organization ISO/IEC JTC1 has developed an International Standard, ISO/IS-10918-1 (JPEG Part 1) and an International Draft Standard, ISO/IS-10918-2 (JPEG Part 2), known as the JPEG Standard, for digital compression and coding of continuous-tone still images. (See Annex F for further details.)

A DICOM Transfer Syntax for JPEG Image Compression shall be identified by a UID value, appropriate to its JPEG coding process, chosen from Table A.4-3.

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Table A.4-3
DICOM TRANSFER SYNTAX UIDS FOR JPEG

DICOM Transfer Syntax UID	JPEG coding process	JPEG description
1.2.840.10008.1.2.4.50	1	baseline
1.2.840.10008.1.2.4.51	2(8-bit),4(12-bit)	extended
1.2.840.10008.1.2.4.52	3(8-bit),5(12-bit)	extended
1.2.840.10008.1.2.4.53	6(8-bit),8(12-bit)	spectral selection, non-hierarchical
1.2.840.10008.1.2.4.54	7(8-bit),9(12-bit)	spectral selection, non-hierarchical
1.2.840.10008.1.2.4.55	10(8-bit),12(12-bit)	full progression, non-hierarchical
1.2.840.10008.1.2.4.56	11(8-bit),13(12-bit)	full progression, non-hierarchical
1.2.840.10008.1.2.4.57	14	lossless, non-hierarchical
1.2.840.10008.1.2.4.58	15	lossless, non hierarchical
1.2.840.10008.1.2.4.59	16(8-bit),18(12-bit)	extended, hierarchical
1.2.840.10008.1.2.4.60	17(8-bit),19(12-bit)	extended, hierarchical
1.2.840.10008.1.2.4.61	20(8-bit),22(12-bit)	spectral selection, hierarchical
1.2.840.10008.1.2.4.62	21(8-bit),23(12-bit)	spectral selection, hierarchical
1.2.840.10008.1.2.4.63	24(8-bit),26(12-bit)	full progression, hierarchical
1.2.840.10008.1.2.4.64	25(8-bit),27(12-bit)	full progression, hierarchical
1.2.840.10008.1.2.4.65	28	lossless, hierarchical
1.2.840.10008.1.2.4.66	29	lossless, hierarchical
1.2.840.10008.1.2.4.70	14 (Selection Value 1)	lossless, non-hierarchical, first-order prediction

855

856 Note: DICOM identifies, to increase the likelihood of successful association, three Transfer Syntaxes for
 857 Default JPEG Compression Image processes (see Sections 8.2.1 and 10).

858 If the object allows multi-frame images in the pixel data field, then each frame shall be encoded
 859 separately. Each fragment shall contain encoded data from a single-frame image.

860 For all images, including all frames of a multi-frame image, the JPEG Interchange Format shall be
 861 used (the table specification shall be included).

862 If images with Photometric Interpretation (0028,0004) YBR_FULL_422 or YBR_PARTIAL_422, are
 863 encoded with JPEG coding Process 1 (non hierarchical with Huffman coding), identified by DICOM
 864 Transfer Syntax UID 1.2.840.10008.1.2.4.50 the minimum compressible unit is YYC_BC_R, where Y,
 865 C_B, and C_R are 8 by 8 blocks of pixel values. The data stream encodes two Y blocks followed by the
 866 corresponding C_B and C_R blocks.

867 A.4.2 RLE COMPRESSION

868 Annex G defines a RLE Compression Transfer Syntax. This transfer Syntax is identified by the UID
 869 value 1.2.840.10008.1.2.5. If the object allows multi-frame images in the pixel data field, then each
 870 frame shall be encoded separately. Each frame shall be encoded in one and only one Fragment
 871 (see PS 3.5.8.2).

872 A.4.3 JPEG-LS IMAGE COMPRESSION

873 The International Standards Organization ISO/IEC JTC1 has developed an International Standard,
 874 ISO/IS-14495-1 (JPEG-LS Part 1), for digital compression and coding of continuous-tone still images.
 875 (See Annex F for further details.)

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876 A DICOM Transfer Syntax for JPEG-LS Image Compression shall be identified by a UID value,
 877 appropriate to its JPEG-LS coding process.

878 Two Transfer Syntaxes are specified for JPEG-LS:

- 879 1. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.80, which specifies the use of the
 880 lossless mode of JPEG-LS. In this mode the absolute error between the source and
 881 reconstructed images will be zero.
- 882 2. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.81, which specifies the use of the
 883 near-lossless mode of JPEG-LS. In this mode, the absolute error between the source and
 884 reconstructed images will be constrained to a finite value that is conveyed in the
 885 compressed bit stream. Note that this process can, at the discretion of the encoder, be
 886 used to compress images with an error constrained to a value of zero, resulting in no loss
 887 of information.

888 If the object allows multi-frame images in the pixel data field, then each frame shall be encoded
 889 separately. Each fragment shall contain encoded data from a single-frame image.

890 For all images, including all frames of a multi-frame image, the JPEG-LS Interchange Format shall
 891 be used (all parameter specifications shall be included).

892 A.4.4 JPEG 2000 IMAGE COMPRESSION

893 The International Standards Organization ISO/IEC JTC1 has developed an International
 894 Standard, ISO/IS 15444-1 (JPEG 2000 Part 1), for digital compression and coding of continuous-
 895 tone still images. (See Annex F for further details.)

896 A DICOM Transfer Syntax for JPEG 2000 Image Compression shall be identified by a UID value,
 897 appropriate to ~~its~~ the choice of JPEG-LS 2000 coding process.

898 Two Transfer Syntaxes are specified for JPEG 2000:

- 899 1. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.90, which specifies the use of the
 900 ~~lossless (reversible)~~ mode of JPEG 2000 Part 1 (ISO/IS 15444-1) (i.e. the use of a
 901 reversible wavelet transformation and a reversible color component transformation,
 902 if applicable, and no quantization).
- 903 2. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.91, which specifies the use of the
 904 ~~lossy (irreversible)~~ mode of JPEG 2000 Part 1 (ISO/IS 15444-1) (i.e. the use of an
 905 irreversible wavelet transformation and an irreversible color component
 906 transformation, if applicable, and optionally quantization).

907 Note: When using the ~~lossy (irreversible)~~ mode, even if no quantization is performed, some
 908 loss will always occur due to the finite precision of the calculation of the wavelet and
 909 multi-component transformations.

911 Only the features defined in JPEG 2000 Part 1 (ISO/IEC 15444-1) are permitted for these two
 912 Transfer Syntaxes. Additional features and extensions that may be defined in other parts of
 913 JPEG 2000 shall not be included in the compressed bitstream unless they can be decoded or
 914 ignored without loss of fidelity by all Part 1 compliant implementations.

915 If the object allows multi-frame images in the pixel data field, then each frame shall be encoded
 916 separately. Each fragment shall contain encoded data from a single-frame image.

917 Note: That is, the processes defined in ISO/IEC 15444-1 shall be applied on a per-frame basis. The
 918 proposal for encapsulation of multiple frames in a non-DICOM manner in so-called "Motion-
 919 JPEG" or "M-JPEG" defined in 15444-3 are not used.

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921 | **For all images, including all frames of a multi-frame image, the JPEG 2000 bitstream specified**
 922 **in ISO/IEC 15444-1 shall be used. The optional JP2 file format header shall NOT be included.**

923 | **Note: The role of the JP2 file format header is fulfilled by the non-pixel data attributes in the DICOM**
 924 **data set.**

925

926

927

928

929 | **Add JPEG 2000 requirements to Annex F:**

930 | **Annex F**
 931 | **(Informative)**
 932 | **Encapsulated images as part of a DICOM message**

933 | The following remarks apply generally to communicating an encoded image within a message
 934 | structure according to the DICOM Standard:

- 935 | a) In the course of including an encoded image in a DICOM message, the encoding is not
 936 | changed. The encoded data stream is merely segmented and encapsulated according to
 937 | the protocols of the DICOM Standard. After unpacking the DICOM message, the encoded
 938 | data stream can be fully reconstructed at the receiving node.
- 939 | b) The object definition of the DICOM Standard is always determining format and other
 940 | choices that a specific encoding implementation may offer. The encoded image must be
 941 | consistent with the definition of the object of which the encoded image is part. For
 942 | example:
 - 943 | 1) If the object is defined to contain 10-bit pixel data, it is assumed that the encoding
 944 | process is one that accepts at least 10-bit data. Hence, there is no need for defining
 945 | separate Transfer Syntaxes, e.g. for 8-bit or 12-bit implementations. Any 12-bit
 946 | implementation is assumed to operate in an 8-bit process if the object is defined to
 947 | contain 8-bit data.
 - 948 | 2) If the image of an object is interleaved, the encoding process must reproduce the
 949 | interleaving.
- 950 | c) Specifications in the encoding file header must be consistent with the DICOM Message
 951 | header, e.g. regarding the number of rows and columns.
- 952 | d) The byte order specification of an encoded file is not altered in the course of
 953 | encapsulating it in a DICOM message.

954 | **F.1 ENCAPSULATED JPEG ENCODED IMAGES**

955 | The International Standards Organization (ISO/IEC JTC1/SC2/WG10) has prepared an International
 956 | Standard, ISO/IS-10918-1 (JPEG Part 1) and International Draft Standard ISO/IS-10918-2 (JPEG
 957 | Part 2), for the digital compression and coding of continuous-tone still images. This standard is
 958 | collectively known as the JPEG Standard.

959 | Part 1 of the JPEG Standard sets out requirements and implementation guidelines for the coded
 960 | representation of compressed image data to be interchanged between applications. The processes
 961 | and representations are intended to be generic in order to support the broad range of applications
 962 | for color and grayscale still images for the purpose of communications and storage within computer
 963 | systems. Part 2 of the JPEG Standard defines tests for determining whether implementations

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964 comply with the requirements of the various encoding and decoding processes specified in Part 1 of
 965 the JPEG Standard.

966 The JPEG Standard specifies lossy and lossless code processes. The lossy coding is based on the
 967 discrete cosine transform (DCT), permitting data compression with an adjustable compression ratio.
 968 The lossless coding employs differential pulse code modulation (DPCM).

969 The JPEG Standard permits a variety of coding processes for the coder and decoder. These
 970 processes differ in coding schemes for the quantified data and in sample precision. The coding
 971 processes are consecutively numbered as defined in the International Draft Standard ISO/IS-10918-
 972 2 (JPEG Part 2), and are summarized in Table F.1-1. The simplest DCT-based coding process is
 973 referred to as Baseline Sequential with Huffman Coding for 8-bit Samples.

974
 975 **Table F.1-1**
JPEG MODES OF IMAGE CODING

No.	Description	Lossy LY Lossles s LL	Non- Hierarchica l NH Hierarchica l H	Sequential S Progressive P	Transform	Coding	Accepted Bits
1	Baseline	LY	NH	S	DCT	Huffman	8
2	Extended	LY	NH	S	DCT	Huffman	8
3	<u>Extended</u>	LY	NH	S	DCT	Arithmeti c	8
4	Extended	LY	NH	S	DCT	Huffman	12
5	<u>Extended</u>	LY	NH	S	DCT	Arithmeti c	12
6	<u>Spectral selection only</u>	LY	NH	P	DCT	Huffman	8
7	<u>Spectral selection only</u>	LY	NH	P	DCT	Arithmeti c	8
8	<u>Spectral selection only</u>	LY	NH	P	DCT	Huffman	12
9	<u>Spectral selection only</u>	LY	NH	P	DCT	Arithmeti c	12
10	<u>Spectral selection only</u>	LY	NH	P	DCT	Huffman	8
11	<u>Spectral selection only</u>	LY	NH	P	DCT	Huffman	8
12	<u>Spectral selection only</u>	LY	NH	P	DCT	Arithmeti c	12
13	<u>Full progression</u>	LY	NH	P	DCT	Huffman	12
	<u>Full progression</u>					Arithmeti c	
	<u>Full progression</u>					Huffman	
	<u>Full progression</u>					Arithmeti c	
14	Lossless	LL	NH	S	DPCM	Huffman	2-16
15	<u>Lossless</u>	LL	NH	S	DPCM	Arithmeti c	2-16
16	<u>Extended sequential</u>	LY	H	S	DCT	Huffman	8
17	<u>Extended sequential</u>	LY	H	S	DCT	Arithmeti c	8
18	<u>Extended sequential</u>	LY	H	S	DCT	Huffman	12
19	<u>Extended sequential</u>	LY	H	S	DCT	Arithmeti c	12
20	<u>Spectral selection only</u>	LY	H	P	DCT	Huffman	8
21	<u>Spectral selection only</u>	LY	H	P	DCT	Arithmeti c	8
22	<u>Spectral selection only</u>	LY	H	P	DCT	Huffman	12
23	<u>Spectral selection only</u>	LY	H	P	DCT	Arithmeti c	12
24	<u>Spectral selection only</u>	LY	H	P	DCT	Huffman	8

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25	Spectral selection only	LV	H	P	DCT	Huffman	8
26	Full progression	LV	H	P	DCT	Arithmeti c	12
27	Full progression	LV	H	P	DCT	Huffman	12
	Full progression					Arithmeti c	
	Full progression					Huffman	
28	Lossless	LL	H	S	DPCM	Huffman	2-16
29	Lossless	LL	H	S	DPCM	Arithmeti c	2-16

976

977 The different coding processes specified in the JPEG Standard are closely related. By extending the
978 capability of an implementation, increasingly more 'lower level' processes can also be executed by
979 the implementation. This is shown in Tables F.1-2 and F.1-3 for Huffman and Arithmetic Coding,
980 respectively. Table F.1-4 presents the capabilities for lossless implementations.

It is worth recognizing that implementations using arithmetic coding have the capability of performing Huffman-coded operations with two Huffman tables since they must be able to execute the baseline process. Hence, by increasing the capability of operating with two additional Huffman tables, the odd-numbered coding processes with arithmetic coding (Table F.1-1) can also execute all corresponding even-numbered processes with Huffman coding (Table F.1-5).

Inclusion of a JPEG-coded image in a DICOM message is facilitated by the use of specific Transfer Syntaxes which are defined in Annex A. Independent of the JPEG coding processes, the same syntax applies. The only distinction for different processes in the syntax is the UID value. Table F.1-5 lists the UID values in the Transfer Syntax for the various JPEG coding processes for reference.

Table F.1-2
RELATIONSHIP BETWEEN THE LOSSY JPEG HUFFMAN CODING PROCESSES
 * Coding process of column can execute coding process of row

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Table F.1-3
RELATIONSHIP BETWEEN THE LOSSY JPEG ARITHMETIC CODING PROCESSES
 * Coding process of column can execute coding process of row

Process	4	3	5	7	9	11	13	17	19	21	23	25	27
4*	*	*	*	*	*	*	*	*	*	*	*	*	*
3		*	*	*	*	*	*	*	*	*	*	*	*
5			*		*		*		*		*		*
7				*	*	*	*			*	*	*	*
9					*					*			*
11						*	*					*	*
13							*						*
17								*	*	*	*	*	*
19									*		*		*
21										*	*	*	*
23											*		*
25												*	*
27													*

998

999 + The Baseline Coding Process, which uses Huffman encoding, is required by all lossy coding processes.

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Table F.1-4
RELATIONSHIP BETWEEN THE LOSSLESS JPEG PROCESSES
 * Coding process of column can execute coding process of row

Process	44	45	28	29
44	*		*	
45		*		*
28			*	
29				*

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Table F.1-5
IDENTIFICATION OF JPEG CODING PROCESSES IN DICOM

DICOM Transfer Syntax UID	JPEG process	JPEG description	capable of performing	lossy arithmetic coding w/opt. 4 Huffman tables
1.2.840.10008.1.2.4.50	1	baseline	1	
1.2.840.10008.1.2.4.51	2,4	extended	1,2,4	
1.2.840.10008.1.2.4.52	3,5	extended	1,3,5	ALL ≤ 5
1.2.840.10008.1.2.4.53	6,8	spect. select. NH	1,2,4,6,8	
1.2.840.10008.1.2.4.54	7,9	spect. select. NH	1,3,5,7,9	ALL ≤ 9
1.2.840.10008.1.2.4.55	10,42	full progression NH	1,2,4,6,8,10,12	
1.2.840.10008.1.2.4.56	11,13	full progression NH	1,3,5,7,9,11,13	ALL ≤ 13
1.2.840.10008.1.2.4.57	14	lossless NH	14	
1.2.840.10008.1.2.4.58	45	lossless NH	45	
1.2.840.10008.1.2.4.59	16,18	extended H	1,2,4,16,18	
1.2.840.10008.1.2.4.60	17,19	extended H	1,3,5,17,19	1,2,3,4,5,16,17,18,19
1.2.840.10008.1.2.4.61	20,22	spect. select.H	1,2,4,6,8,16,18,20,22	
1.2.840.10008.1.2.4.62	21,23	spect. select. H	1,3,5,7,9,17,19,21,23	1,2,3,4,5,6,7,8,9,16,17,18,19,20,21,22,23
1.2.840.10008.1.2.4.63	24,26	full progression H	1,2,4,6,8,10,12,16,18 , 20,22,24,26	
1.2.840.10008.1.2.4.64	25,27	full progression H	1,3,5,7,9,11,13,17,19 , 21,23,25,27	ALL ≤ 27, EXCEPT 14,15
1.2.840.10008.1.2.4.65	28	lossless H	14,28	
1.2.840.10008.1.2.4.66	29	lossless H	15,29	
1.2.840.10008.1.2.4.70	14 Selection Value 1	lossless NH, first-order prediction		

1006

F.2 ENCAPSULATED JPEG-LS ENCODED IMAGES

1008 The International Standards Organization (ISO/IEC JTC1/SC2/WG10) has prepared an International
 1009 Standard, ISO/IS-14495-1 (JPEG-LS Part 1), for the digital compression and coding of continuous-
 1010 tone still images. This standard is known as the JPEG-LS Standard.

1011 Part 1 of the JPEG-LS Standard sets out requirements and implementation guidelines for the coded
 1012 representation of compressed image data to be interchanged between applications. The processes
 1013 and representations are intended to be generic in order to support the broad range of applications
 1014 for color and grayscale still images for the purpose of communications and storage within computer
 1015 systems.

1016 The JPEG-LS Standard specifies a single lossy (near-lossless) code process that can achieve
 1017 lossless compression by constraining the absolute error value during encoding to zero. The lossless
 1018 and lossy (near-lossless) coding is based on a predictive scheme with statistical modeling, in which
 1019 differences between pixels and their surround are computed and their context modeled prior to

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1020 coding, with a run-length escape mechanism. This scheme achieves consistently better compression
1021 in lossless mode than the lossless processes of JPEG defined in ISO 10918-1, with less complexity.

1022 Though a different coding process from those specified in ISO 10918-1 is used, the syntax of the
1023 encoded bit stream is closely related.

1024 A single JPEG-LS process is used for bit depths up to 16 bits.

1025 Inclusion of a JPEG-LS coded image in a DICOM message is facilitated by the use of specific
1026 Transfer Syntaxes that are defined in Annex A.

1027 **F.3 ENCAPSULATED JPEG 2000 ENCODED IMAGES**

1028 The International Standards Organization (ISO/IEC JTC1/SC2/WG10) has prepared an
1029 International Standard, ISO/IS-15444-1 (JPEG 2000 Part 1), for the digital compression and
1030 coding of continuous-tone still images. This standard is known as the JPEG 2000 Standard.

1031 Part 1 of the JPEG 2000 Standard sets out requirements and implementation guidelines for the
1032 coded representation of compressed image data to be interchanged between applications. The
1033 processes and representations are intended to be generic in order to support the broad range
1034 of applications for color and grayscale still images for the purpose of communications and
1035 storage within computer systems.

1036 The JPEG 2000 Standard specifies

1037 Though a different coding process from those specified in ISO 10918-1 is used, the syntax of
1038 the encoded bit stream is closely related.

1039 A single JPEG 2000 process is used for bit depths up to 16 bits.

1040 Inclusion of a JPEG 2000 coded image in a DICOM message is facilitated by the use of specific
1041 Transfer Syntaxes that are defined in Annex A.

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1050 **Changes to**

1051 **NEMA Standards Publication PS 3.6-2000**

1052

1053 *Digital Imaging and Communications in Medicine (DICOM)*

1054 *Part 6: Data Dictionary*

1055

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1057

Add new UIDs to Annex xx:1058
1059**Annex A Registry of DICOM unique identifiers (UID)
(Normative)**1060 Table A-1 lists the UID values which are registered and used throughout the Parts of the DICOM
1061 Standard. This central registry ensures that when additional UIDs are assigned, non duplicate values
1062 are assigned.1063
1064**Table A-1
UID VALUES**

UID Value	UID NAME	UID TYPE	Part
1.2.840.10008.1.1	Verification SOP Class	SOP Class	PS 3.4
1.2.840.10008.1.2	Implicit VR Little Endian: Default Transfer Syntax for DICOM	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.1	Explicit VR Little Endian	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.2	Explicit VR Big Endian	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.50	JPEG Baseline (Process 1): Default Transfer Syntax for Lossy JPEG 8 Bit Image Compression	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.51	JPEG Extended (Process 2 & 4): Default Transfer Syntax for Lossy JPEG 12 Bit Image Compression (Process 4 only)	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.52	<i>JPEG Extended (Process 3 & 5) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.53	<i>JPEG Spectral Selection, Non-Hierarchical (Process 6 & 8) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.54	<i>JPEG Spectral Selection, Non-Hierarchical (Process 7 & 9) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.55	<i>JPEG Full Progression, Non-Hierarchical (Process 10 & 12) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.56	<i>JPEG Full Progression, Non-Hierarchical (Process 11 & 13) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>

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1.2.840.10008.1.2.4.57	JPEG Lossless, Non-Hierarchical (Process 14)	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.58	<i>JPEG Lossless, Non-Hierarchical (Process 15) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.59	<i>JPEG Extended, Hierarchical (Process 16 & 18) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.60	<i>JPEG Extended, Hierarchical (Process 17 & 19) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.61	<i>JPEG Spectral Selection, Hierarchical (Process 20 & 22) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.62	<i>JPEG Spectral Selection, Hierarchical (Process 21 & 23) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.63	<i>JPEG Full Progression, Hierarchical (Process 24 & 26) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.64	<i>JPEG Full Progression, Hierarchical (Process 25 & 27) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.65	<i>JPEG Lossless, Hierarchical (Process 28) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.66	<i>JPEG Lossless, Hierarchical (Process 29) (Retired)</i>	<i>Transfer Syntax</i>	<i>PS 3.5</i>
1.2.840.10008.1.2.4.70	JPEG Lossless, Non-Hierarchical, First-Order Prediction (Process 14 [Selection Value 1]): Default Transfer Syntax for Lossless JPEG Image Compression	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.80	JPEG-LS Lossless Image Compression	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.81	JPEG-LS Lossy (Near-Lossless) Image Compression	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.90	<u>JPEG-LS 2000 Lossless Image Compression</u>	<u>Transfer Syntax</u>	<u>PS 3.5</u>
1.2.840.10008.1.2.4.91	<u>JPEG-LS 2000 Lossy Image Compression</u>	<u>Transfer Syntax</u>	<u>PS 3.5</u>
1.2.840.10008.1.2.5	RLE Lossless	Transfer Syntax	PS 3.5
1.2.840.10008.1.3.10	Media Storage Directory Storage	SOP Class	PS 3.4

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1074 **Changes to**

1075 **NEMA Standards Publication PS 3.11-2000**

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1077 *Digital Imaging and Communications in Medicine (DICOM)*

1078 *Part 11: Media Application Profiles*

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1081 *Add any new profiles that use the JPEG 2000 transfer syntaxes here:*

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